NATURAL REGENERATION of Douglas-fir and Associated Species using modified clear-cutting systems in the Oregon Cascades

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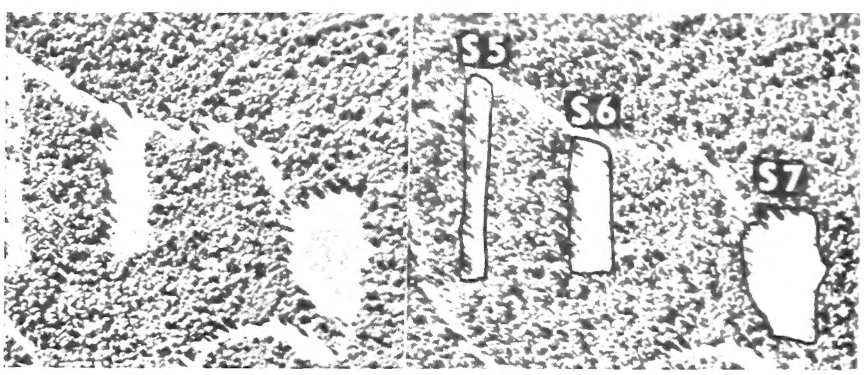

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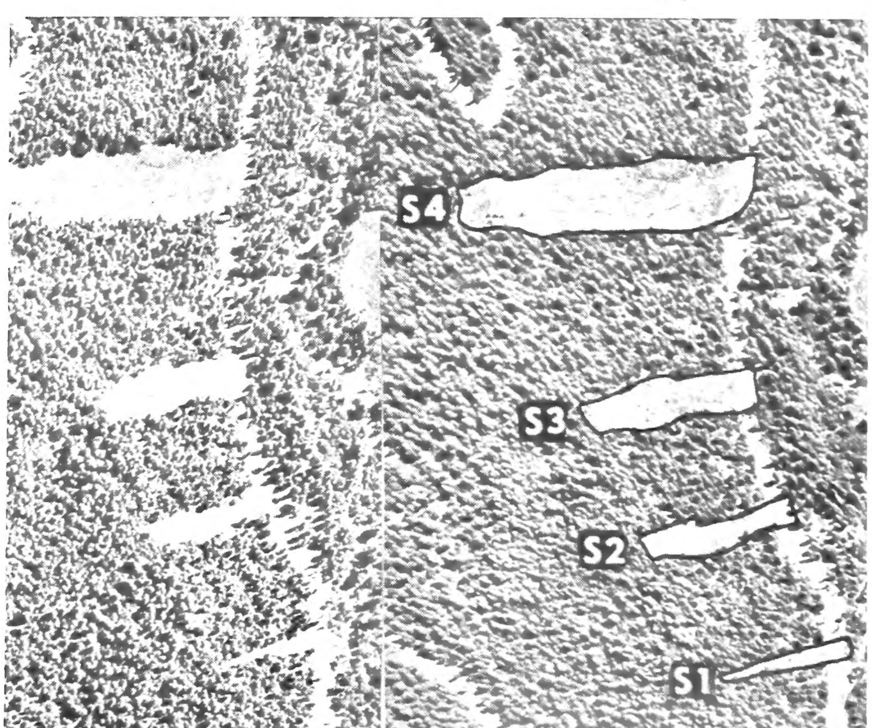

Top: Aerial stereogram of standard clear cut (5B), seed-tree cutting (5C), and patch clear cuts from 1/4 to 4 acres in size (G6 through G1).

Middle: Aerial stereogram of east-west oriented strip clear cuts 100 to 300 feet in width (S5 through S7).

Bottom: Aerial stereogram of north-south oriented strip clear cuts 50 to 350 feet in width (S1 through S4).

INTRODUCTION

Clear cutting is the standard harvesting system in old-growth Douglas-fir (Pseudotsuga menziesii) forests in the Pacific Northwest. Usually these clear cuts are in "staggered settings" of 15 to 80 acres with the surrounding stand left uncut to provide seed and serve as a firebreak. However, satisfactory natural regeneration of Douglas-fir does not always develop on such cuttings. The erratic and infrequent occurrence of abundant Douglas-fir seed crops and high surface soil temperatures appear to be major deterrents in many areas. Consequently, some modified clear cuts were tried in old-growth Douglas-fir in the western Oregon Cascade Range in 1954 and 1955 to determine their effect on natural regeneration. Cutting was in small patches and in strips of various widths and orientations. One trial of the seed-tree method was included. Cuttings were designed to leave residual trees in patterns that would reduce surface soil temperatures by providing shade and also improve distribution of natural seed fall. Resultant regeneration was examined in the summer of 1959.

STUDY AREAS

The study areas are located in the H. J. Andrews Experimental Forest on Lookout Creek, a tributary of McKenzie River in the western Oregon Cascades. Timber type before cutting was 400-year-old Douglas-fir with considerable western hemlock (Tsuga heterophylla) and some western redcedar (Thuja plicata). Merchantable timber volumes averaged 50,000 to 100,000 board feet per acre. Precipitation is heavy, in excess of 80 inches annually, and temperatures are mild, averaging 65° F. during the growing season (Berntsen and Rothacher, 1959).

Five general types of cuttings were tried: (1) Clear cutting in strips oriented north and south, (2) clear cutting in strips oriented east and west, (3) clear cutting in small patches ranging from 1/4 acre to 4 acres in size, (4) a seed-tree cutting, and (5) a staggered-setting clear cutting (table 1). Areas were cut and slash burned in 1954 and 1955. Considerable mineral soil seedbed was exposed in all treatments. Surface soils are clay loam in texture on all cuttings. Ground cover at time of the 1959 examination was relatively uniform with no outstanding differences among cutting units.[1/]

[1/] For a discussion of vegetative composition and coverage on clear cuts in this area, the reader is referred to Yerkes (1960).

Table 1.--Physical and historical data on modified cutting units,

H. J. Andrews Experimental Forest

Shape and number of unit	Size	Dimensions			Average slope	Average elevation	Year	
		Width	Length	Radius			Logged	Burned
	Acres	Feet			Percent	Feet		
North-south oriented strip clear cuts:								
S1	0.7	50	600	--	60	2,025	1954	1954
S2	1.2	100	550	--	60	2,100	1954	1954
S3	3.6	200	800	--	50	2,125	1954	1955
S4	8.4	350	1,050	--	40	2,175	1954	1955
East-west oriented strip clear cuts:								
S5	2.3	100	1,000	--	10	2,550	1954	1954
S6	3.1	200	650	--	10	2,600	1954	1954
S7	4.0	300	575	--	20	2,650	1954	1955
Rectangular patch clear cuts:								
G1	4.0	435	400	--	20	3,100	1955	1955
G2	2.0	250	350	--	10	3,125	1955	1955
G3	1.0	200	220	--	0	3,075	1955	1955
Circular patch clear cuts:								
G4	.75	--	--	102	0	3,025	1955	1955
G5	.50	--	--	83	10	3,025	1955	1955
G6	.25	--	--	49	20	3,050	1955	1955
Staggered-setting clear cut:								
5B	48.4	--	--	--	20	3,200	1955	1955
Seed-tree cutting:								
5C	20.4	--	--	--	10	3,300	1955	1955

Exposure and topography within individual clear cuts are fairly uniform except units S4, 5B, and 5C (table 1), where exposure varies due to presence of minor stream drainages. The north-south strip clear cuts are on a steep, south-facing slope with a relatively shallow soil at an elevation of 1,850 to 2,375 feet. The other cuttings are on a gentle, south-facing slope with deeper soil at elevations ranging from 2,550 to 3,500 feet. Thus, the north-south strip clear cuts occupy a hotter and drier habitat than the other cuttings.

CONE CROPS

Continuous records of Douglas-fir and western hemlock cone crops have been kept on the experimental forest. During the study period, average ratings[2/] were:

Years	Douglas-fir	Western hemlock
1954	Medium	Abundant
1955	Light	Light
1956	Abundant	Medium
1957	Failure	Medium
1958	Failure	Light

FIELD MEASUREMENTS

Species, amount, and distribution of natural regeneration were used as the main criteria for comparing the different types of cuttings. Tree seedlings were counted on milacre plots located along transects. Transects (usually 10 per cutting) were surveyed across cuttings with their direction parallel to the narrow side of the cutting. Number of milacre plots varied from 90 to 225 per cutting, depending in part on size and shape of unit.

A Douglas-fir seedling in its second growing season was considered established; two 1-year-old seedlings were considered its equivalent. A western hemlock or western redcedar seedling in its third season was considered established; three seedlings either 1 or 2 years old were considered its equivalent. For strip and patch clear cuts, hours during which the center of the plot received

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[2/] Data based on averages of general observations of number of cones at seven locations. Ratings provide a relative measure only.

shade from adjacent timber between 6 a.m. and 6 p.m. were estimated, using a technique described by Silen.[3/]

RESULTANT STOCKING

If stocking of any species on 30 percent of the milacre plots is considered adequate, all cuttings except the staggered-setting were adequately stocked with tree seedlings (table 2).[4/] Considering Douglas-fir alone, all cuttings except the staggered-setting and 2-acre patch clear cut were stocked. As groups, the east-west strip clear cuts had the best stocking, north-south strip clear cuts and staggered-setting were poorest, and patch clear cuts and the seed-tree cutting were intermediate.

The staggered-setting clear cut had only 407 Douglas-fir seedlings per acre and 28 percent of the plots stocked with any species.

Poor stocking is typical of many large clear cuts in this general area. For example, twelve 3- to 5-year-old clear cuts on the experimental forest surveyed in 1956 had an average of only 301 (range 81 to 525) Douglas-fir seedlings per acre. Total plots stocked with any species averaged 28 (range 11 to 48) percent and plots stocked with Douglas-fir averaged only 24 (range 9 to 36) percent, even though both 1- and 2-year-old seedlings were included in the tally.

3/ Silen, Roy Ragnar. Lethal surface temperatures and their interpretation for Douglas-fir. Unpublished Ph. D. thesis on file Oreg. State Univ. 170 pp., illus. 1960.

This technique involves use of a protractor placed with the index mark at center of plot and oriented with the 90° mark toward south. Protractor is tilted at a 45° angle toward north to aline its surface with celestial equator. Path of the sun for six spring and summer months lies somewhere in a band 23° wide north of celestial equator marked by protractor edge. Stand edge producing shade must lie within the skyward projection of this imaginary band. Since the sun moves along the band at 15° per hour, hours of shade on each plot can be estimated with the protractor in terms of degrees and then converted to hours. A pencil, with the point held at the center of the plot on the protractor index mark, was swung on the sun's apparent path, and the hours the plot was receiving stand shade were estimated. The principles for such approximations are found in any general surveying textbook.

4/ Thirty percent is the usual 1-milacre stocking criterion used in the Northwest. Percent of milacre plots stocked is not completely satisfactory as a measure of overall adequacy of regeneration on a clear cut, although it is better than number of seedlings per acre. A map showing distribution of stocked plots within a cutting is probably best. In this study, stocked plots were generally well distributed on small cuttings but confined to the outer area of the staggered-setting cutting.

Table 2.--Stocking established seedlings on standard and modified clear cuts, H. J. Andrews Experimental Forest, 1959

Unit	Kind of cutting unit	Milacre plots	Stocking		
			Plots stocked, all species	Plots stocked, Douglas-fir	Douglas-fir seedlings per acre
		Number	Percent	Percent	Number
S1	North-south 50-foot strip	102	61	57	1,466
S2	North-south 100-foot strip	118	35	31	597
S3	North-south 200-foot strip	96	40	34	573
S4	North-south 350-foot strip	141	60	45	908
S5	East-west 100-foot strip	90	81	68	1,733
S6	East-west 200-foot strip	99	89	81	4,561
S7	East-west 300-foot strip	174	69	59	1,899
G1	4-acre square patch	204	58	42	824
G2	2-acre square patch	116	60	29	474
G3	1-acre square patch	102	81	45	814
G4	3/4-acre circular patch	114	75	58	1,658
G5	1/2-acre circular patch	107	72	64	2,276
G6	1/4-acre circular patch	130	72	44	888
5B	Staggered-setting	225	28	21	407
5C	Seed-tree	125	61	50	1,448

The wide variation in level of stocking among units essentially homogeneous in character is noteworthy. For example, the three east-west strip clear cuts occupy similar topography, but percent of plots stocked with Douglas-fir varied from 59 to 81 and number of Douglas-fir seedlings varied from 1,733 to 4,561 per acre.

REGENERATION AND GROSS CHARACTERISTICS OF CLEAR CUTS

The first analyses were made to determine if stocking levels were related to measurable characteristics of the 13 small clear cuts. Three different measures of stocking were used: (1) percent of plots stocked with all species, (2) percent of plots stocked with Douglas-fir, and (3) number of Douglas-fir seedlings per acre. Characteristics of clear cuts were expressed as: (1) size of clear cut, (2) average hours of shade on clear cut, (3) width of clear cut in narrowest dimension, (4) width of clear cut in north-south dimension, and (5) average distance of plots from stand edge. In the regression analyses, all relationships were tested, using each clear cut as a single observation.

Only one relationship was revealed to be significant[5/]--the relation of percent of milacre plots stocked with any species and the north-south width of the clear cut. For the 13 small clear cuts sampled, apparently no relationship exists between stocking of either Douglas-fir or all species and size of clear cut, average hours of shade on clear cut, width of clear cut in narrowest dimension, or average distance of plots from stand edge.

REGENERATION AND CHARACTERISTICS OF MILACRE PLOTS

The failure of the initial analysis to reveal relationships between stocking levels and gross characteristics of clear cuts prompted a closer look at milacre-plot data on individual clear-cut units. Additional regression analyses were carried out to determine if number of Douglas-fir seedlings per plot was related to (1) hours of shade on plot or (2) distance of plot from seed source. These two analyses were conducted for each of the 13 patch and strip clear cuts. In addition, plot data from each of the major groups of cuttings--east-west strips, north-south strips, and patch clear cuts--were pooled and analyzed in the same manner.

Stand Shade

Stand shade favored establishment of natural regeneration. On some cuttings, this was apparent simply from examination of plotted data (fig. 1). The statistical analyses revealed that a significant relationship existed between

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[5/] In this paper, "significant" is used in a statistical sense and means that a relationship was shown to exist at the 5-percent level of probability. "Highly significant" means a relationship was shown to exist at the 1-percent level of probability.

hours of shade and number of Douglas-fir seedlings per plot on 8 of 13 units. The pooled data from all three major types of cuttings showed a highly significant correlation between hours of shade and number of Douglas-fir seedlings per plot.

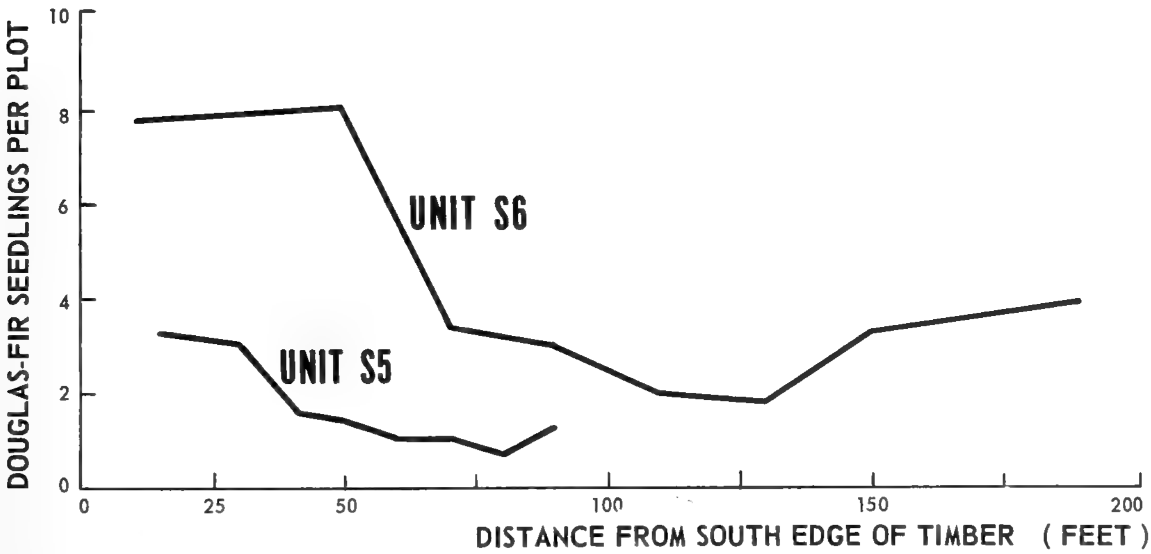

Figure 1.--Relation between stocking and distance from the south edge of timber on two east-west oriented strip clear cuts. Unit S5 is 100 feet wide and unit S6 is 200 feet wide.

In general, the relation between hours of shade and regeneration was more marked on east-west strip clear cuts and patch clear cuts than on north-south strip clear cuts. A partial explanation of differences between units is provided by Silen.[6] He found seedlings must be exposed to a high soil surface temperature for a continuous period of time before heat damage occurs to the seedling. Apparently, intermittent sunlight is less damaging than an equal duration of continuous sunlight. Only part of the variation between units can be explained in this way; other factors, such as time of day plot receives stand shade, pattern of ground shade, and microexposure, doubtless play a major role.

How much shade can be expected from a particular stand edge? The theoretical relationship of tree height, percent slope, angle of sun, and stand shade is shown in figure 2. In practice, this relationship is modified by the continuity and crown condition of the stand providing shade. Plotted results from two units (fig. 1) indicate that a timber edge on the south affects a smaller

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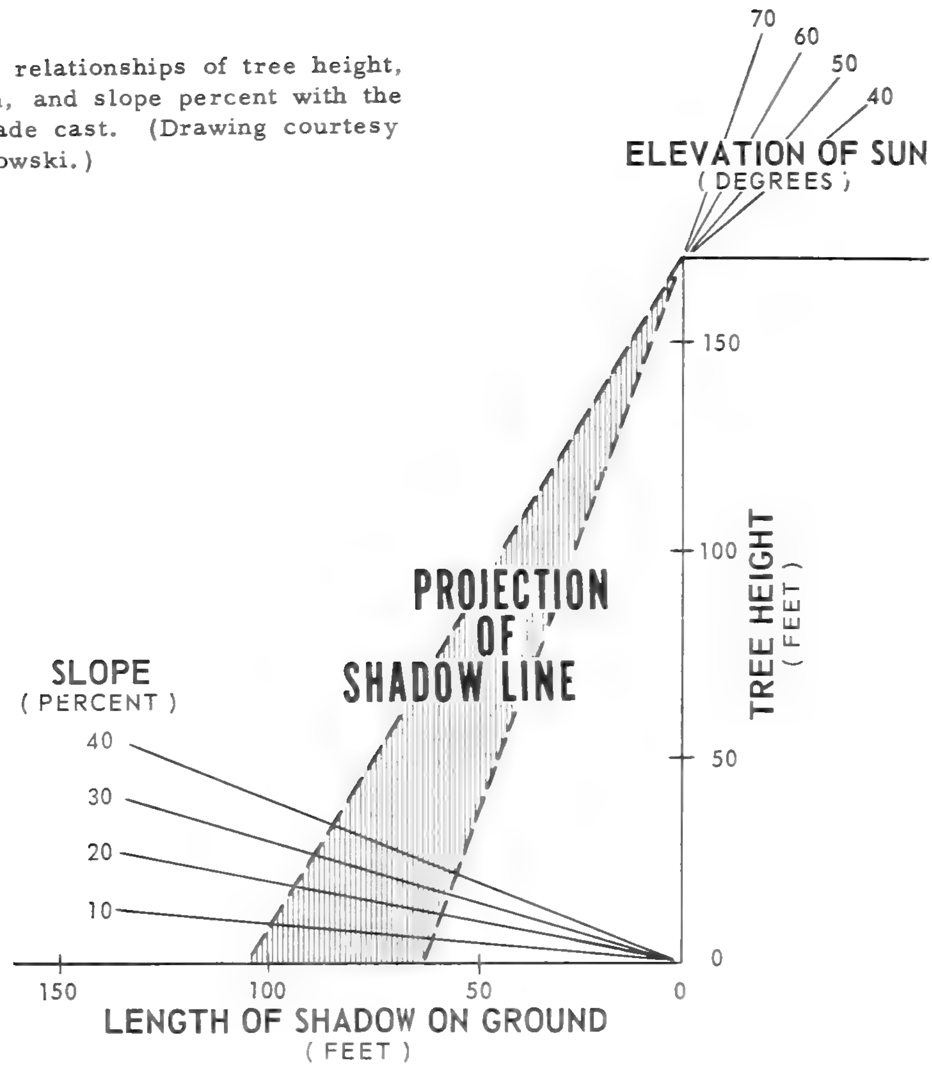
6/ See footnote 3, p. 4.

Figure 2.--Theoretical relationships of tree height, elevation of the sun, and slope percent with the amount of stand shade cast. (Drawing courtesy of Dr. H. J. Gratkowski.)



area than indicated by the diagram. The differences between the obviously shade-influenced areas on these units (approximately 35 feet and 70 feet) reflect differences in the shade effects of the timber edge.[7]

Distance from Seed Source

The number of Douglas-fir seedlings per plot was generally not related to distance from seed source. All portions of strip and patch clear cuts were within 200 feet (and usually much less) of a timber edge. Since Douglas-fir seed is readily carried much greater distances (Isaac, 1943), a relation between stocking and distance from seed source would not be expected on these units. On a few cuttings, there were significant relations between regeneration and distance

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[7] These units were chosen because the relationship between stand shade and stocking is least influenced by extraneous factors such as roads and cutting boundary irregularities.

from stand edge, but these probably resulted from the partial relationship which exists between hours of shade and distance from stand edge. However, on the staggered-setting clear cut, the relation between stocking and distance from stand edge was highly significant:

Distance from stand edge	Total plots	Plots stocked	Percent stocked
Under 200 feet	106	52	49
Over 200 feet	119	10	8

Worthington (1953) reported similar results after studying regeneration on a large clear cut and some small patch clear cuts 1.2 to 4.0 acres in size in western Washington. Distance from stand edge affected stocking only beyond 500 feet on the large clear cut. None of the small patch cuts he studied had sample points over 500 feet from stand edge, and no relation between stocking and distance from stand edge was therefore found on these units.

This also explains the lack of relationship between clear cut size and stocking mentioned earlier. The patch and strip clear cuts were simply too small to show such a relation. Lavender et al. (1956) studied much larger clear cuts and concluded there was no relation between the size of clear cut and regeneration.

DISCUSSION OF THE MODIFIED CUTTINGS

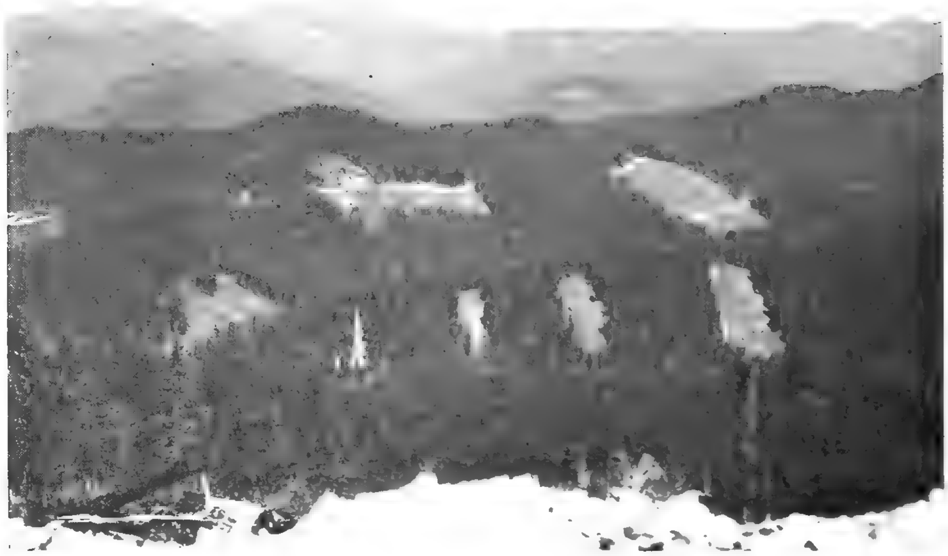
North-South Strip Clear Cuts

Although north-south strip clear cuts had the poorest stocking of the modified cuttings, they were surprisingly well stocked considering the severity of the site. Analysis of the individual north-south strip clear cuts generally indicated no significant relation between number of Douglas-fir seedlings per plot and hours of shade or distance from seed source. Lack of a relation between shade hours and regeneration can be explained, at least in part, by the continuous rather than intermittent character of the shade (fig. 3). There does not appear to be any significant relation between stocking and width of north-south strip.

East-West Strip Clear Cuts

The long timber edge available for shading regeneration on the east-west strip clear cuts was probably responsible for superior stocking on these units. Furthermore, much of the shading was of the intermittent type. Analysis of data from individual units and of the pooled data indicated the number of Douglas-fir seedlings per plot was significantly related to hours of shade.

Figure 3.--Pattern of shading on north-south oriented strip clear cuts. Top, in the morning; middle, at midday; bottom, in the afternoon.



Patch Clear Cuts

Stocking of patch clear cuts was generally intermediate between the east-west and north-south strip clear cuts. As a group, the patch clear cuts showed a consistent relationship between shade and number of Douglas-fir seedlings per plot. Two exceptions were units G2 and G5. Part of unit G2 was a low swampy area which offered little mineral seedbed. More than half of the stocked plots contained western hemlock and/or western redcedar; and 29 percent of the plots were stocked with Douglas-fir. Unit G5 had a road as its southern boundary and the effective environment of this clear cut was larger than its half-acre size would indicate. In addition, a second unit just across the road from G5 was cut in the spring of 1959. This disturbance made it impossible to obtain a valid estimate of amount of shading during the previous 4 years.

Most references to strip and patch clear cutting list the main advantage as a provision for an effective seed source (Haig et al., 1941; Hawley and Smith, 1954; Heinselman, 1959; Lexen, 1949). Hawley and Smith (1954) mention in addition that "...this kind of modification [strips or patches] may also be employed...to create an environmental condition intermediate between the protection of a shelterwood and the drastic exposure of a large clear cut area." Troup (1952) emphasizes the protective function of such cuttings. A system known as Wagner's "Blendersaumschlag" involves narrow strip cuttings oriented east and west which progress from north to south with the specific objective of protecting seedlings from the sun on the strip being regenerated. In European clear-strip systems, cuttings are often restricted to widths no more than the height of adjacent forest in order to secure side protection from the sun for either artificial or natural regeneration. Results of the current study suggest that patch and strip clear cuttings for Douglas-fir are primarily of value in aiding seedling establishment.

Seed-Tree Cutting

The seed-tree cutting was a small staggered-setting on which three dozen Douglas-firs were left on two-thirds of the area to supply seed and shade (fig. 4). Trees were selected for vigor and at a spacing of approximately 120 feet; slash was pulled away from the seed trees during logging to prevent damage during slash burning.

Figure 4.--General view of seed-tree cutting.

The seed-tree portion of unit 5C was well stocked 4 years after logging (table 2). An important factor in prompt seedling establishment was probably the shade cast by seed trees. Garman (1955) found that a full-crowned, mature Douglas-fir seed tree gives temporary protection to an area of one-third acre during critical times of the year. Mineral seedbed resulting from yarding and slash-disposal operations and additional seed produced by seed trees were other important factors. Seed trees have been found to be heavier cone producers and more efficient distributors of seed than marginal timber (Garman, 1951; Isaac, 1940). Poorest stocking was on the portion of the unit without seed trees, but a statistical comparison was not possible because of variations in slope, exposure, steepness, and edge-shade effects.

Careful selection of sound, vigorous, and apparently windfirm seed trees and prevention of damage to them during logging-slash burning resulted in almost 100-percent seed-tree survival. None of the Douglas-fir trees left in 1955 had blown down and only two had died from exposure as of September 1961. Most were full crowned and had been producing seed.

Several studies of Douglas-fir regeneration have indicated the value of seed trees for regeneration. Garman (1955) found that shade definitely improved seedling survival in British Columbia. He felt that shade from two to eight seed trees per acre was indicated on severe sites and that cutting of Douglas-fir would eventually evolve to harvesting in 300-foot-wide strips (on good sites) and a shelterwood system on more severe sites. He concluded, "Douglas-fir should be cut by a method that leaves the shade of scattered seed trees." Bever (1954), following a study of factors affecting natural regeneration in central western Oregon, concluded the seed-source value of seed trees was higher than marginal timber or seed blocks. In contrast, early studies of seed trees indicated mortality, wind, logging, and slash burning quickly destroyed most of the trees (Isaac, 1940).

CONCLUSIONS

Strip and patch clear cuttings and a seed-tree cutting were adequately stocked with seedlings of Douglas-fir and associated species within 4 years after logging and slash burning. There was, however, a great deal of variability in level of stocking between and within the experimental cuttings. A staggered-setting clear cut of comparable age was not adequately stocked. Quantity of Douglas-fir regeneration was not related to gross characteristics of the cutting areas such as size or width. However, stocking of seedlings of all species was related to the north-south width of the clear cut. Analyses of the plot data from individual clear cuts showed that, of several factors studied, number of hours of stand shade on a plot was most closely related to number of Douglas-fir seedlings. Regeneration was not related to distance from seed source on the relatively small patch and strip clear cuts.

The chief value of modified cutting systems appeared to be in seedling establishment, particularly through reduction of insolation losses. Intermittent

shade may have been more effective than a similar amount of shade received in a single period of time, although this was not demonstrated conclusively.

It is recommended that consideration be given to the use of modified cutting methods such as east-west strip clear cuts, small patch clear cuts, and seed-tree cuttings to improve natural restocking of Douglas-fir on sites difficult to regenerate. Such cuttings should be laid out primarily to provide shade and secondarily to favor seed dispersal.

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